From DER Optimization to a Multi-Layered Microgrid Controller

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Infocast's 5th Military & Commercial Microgrids Summit 2014

19 November 2014

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http://building-microgrid.lbl.gov/

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

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Partners: Brookhaven National Laboratory, EPRI, Fort Hunter Liggett (US DoD), Massachusett Institute of Technology (MIT), MIT Lincoln Laboratory, NEC, Public Service New Mexico, TriTechnic, University of New Mexico, University of San Diego, Universidad Pontificia Comillas – IIT, …

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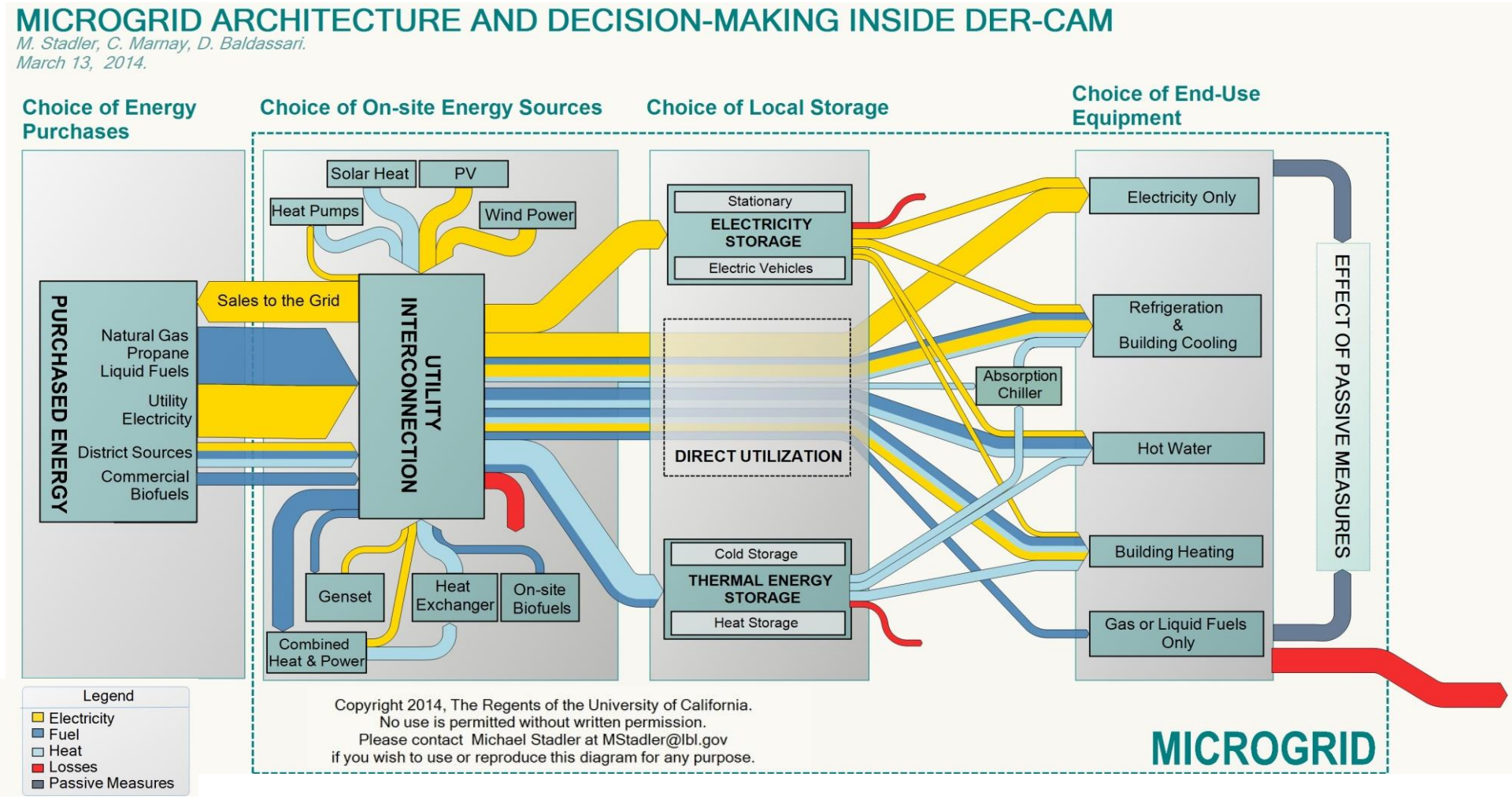
Global Concept for Buildings and Microgrids



Distributed Energy Resources Customer Adoption Model (DER-CAM)

- is a deterministic and stochastic Mixed Integer Linear Program (MILP), written in the General Algebraic Modeling System (GAMS®)
- started as a building CHP optimization tool
- supported by the U.S. DOE, OE, DoD, CEC, private industry
- two main objective functions:
  - cost minimization
  - CO_2 minimization
- other objectives are possible, as well as multi-objective, subject to microgrid/building constraints and energy balance
- produces optimal investment and dispatch results for biogas/diesel/natural gas CHP, fuel cells, ICE, micro-turbines, gas-turbines; PV, solar thermal, hot and cold water storage, batteries, heat pumps, absorption chiller, EV, passive measures (insulation, window changes, etc..)

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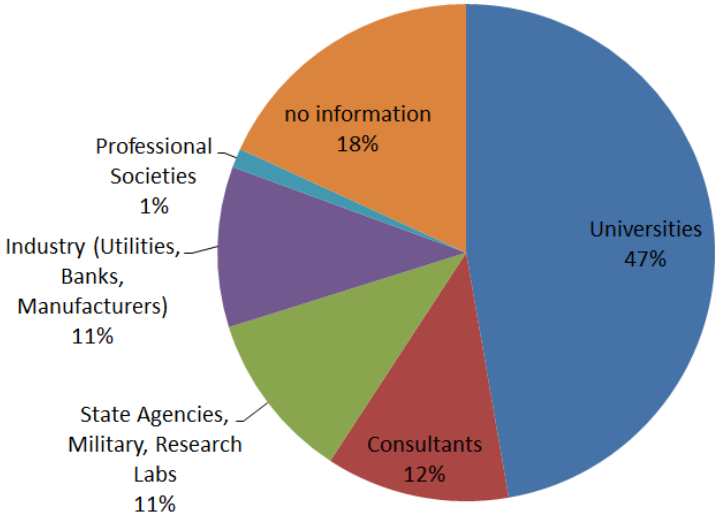
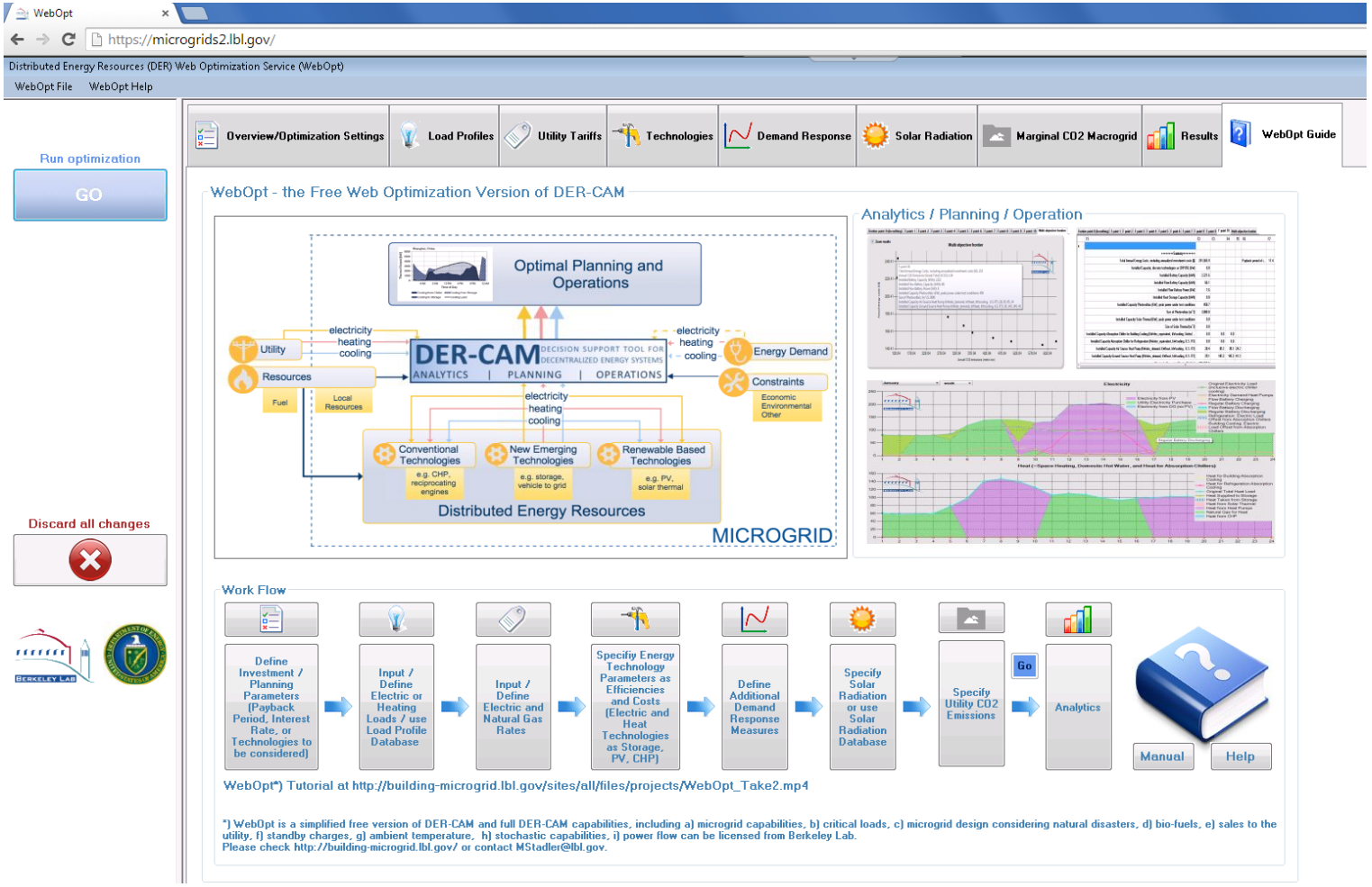
- optimizes heating, cooling, electricity, and fuel loads (as natural gas)
- can consider real microgrid conditions as islanding and critical loads
- very specific versions exist (http://building-microgrid.lbl.gov/sites/all/files/projects/DER-CAM-Feature-List.pdf)
- commercialization and predictive controller work under way
- DER-CAM *web clients* (English and Chinese version)



Web DER-CAM (WebOpt) users by business type

Web DER-CAM user map

Transferability: Online DER-CAM User Guide



http://building-microgrid.lbl.gov/projects/how-access-der-cam

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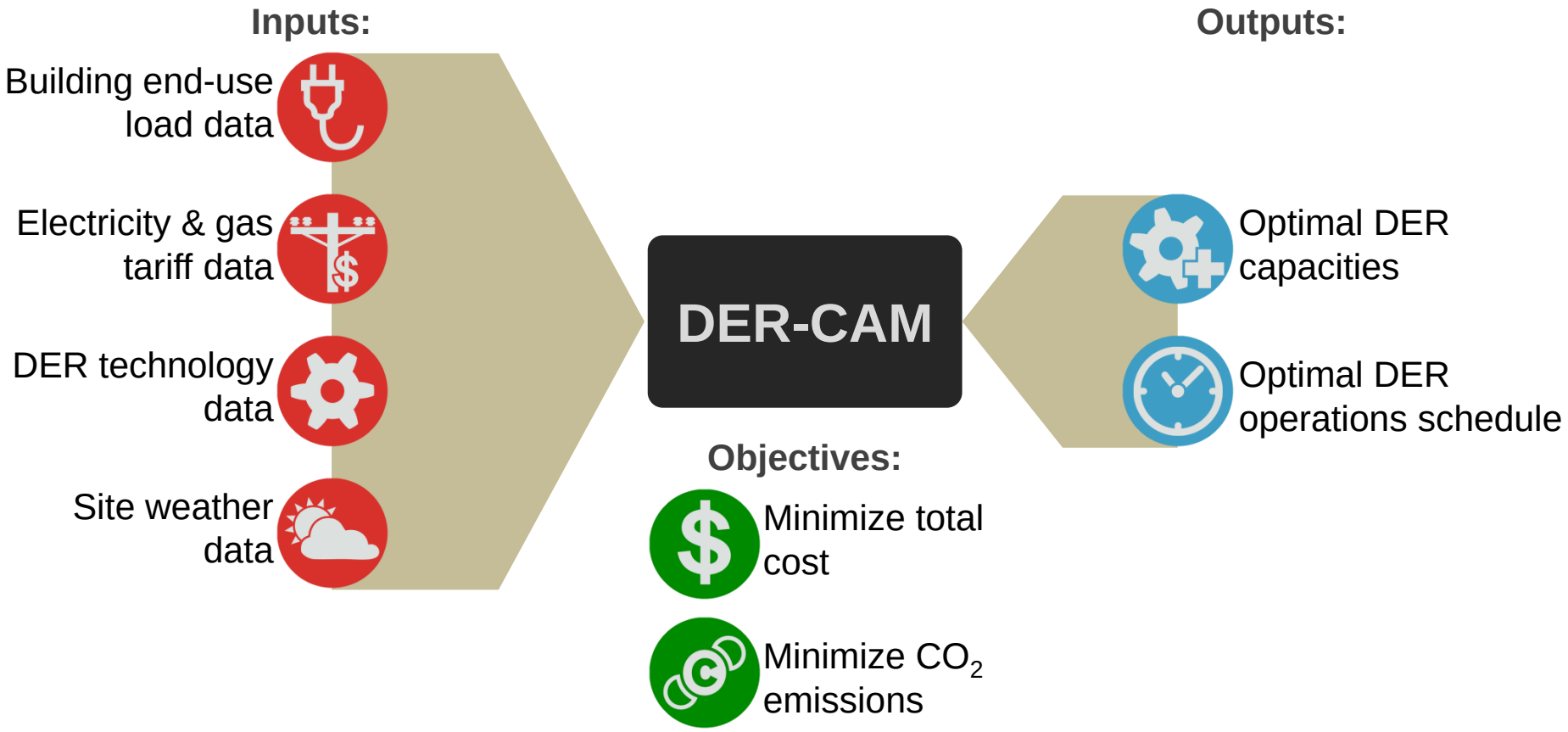

- **Investment & Planning:** determines optimal equipment combination and operation based on *historic* load data, weather, and tariffs
- **Operations:** determines optimal week-ahead scheduling for installed equipment and *forecasted* loads, weather and tariffs→ used for Controller

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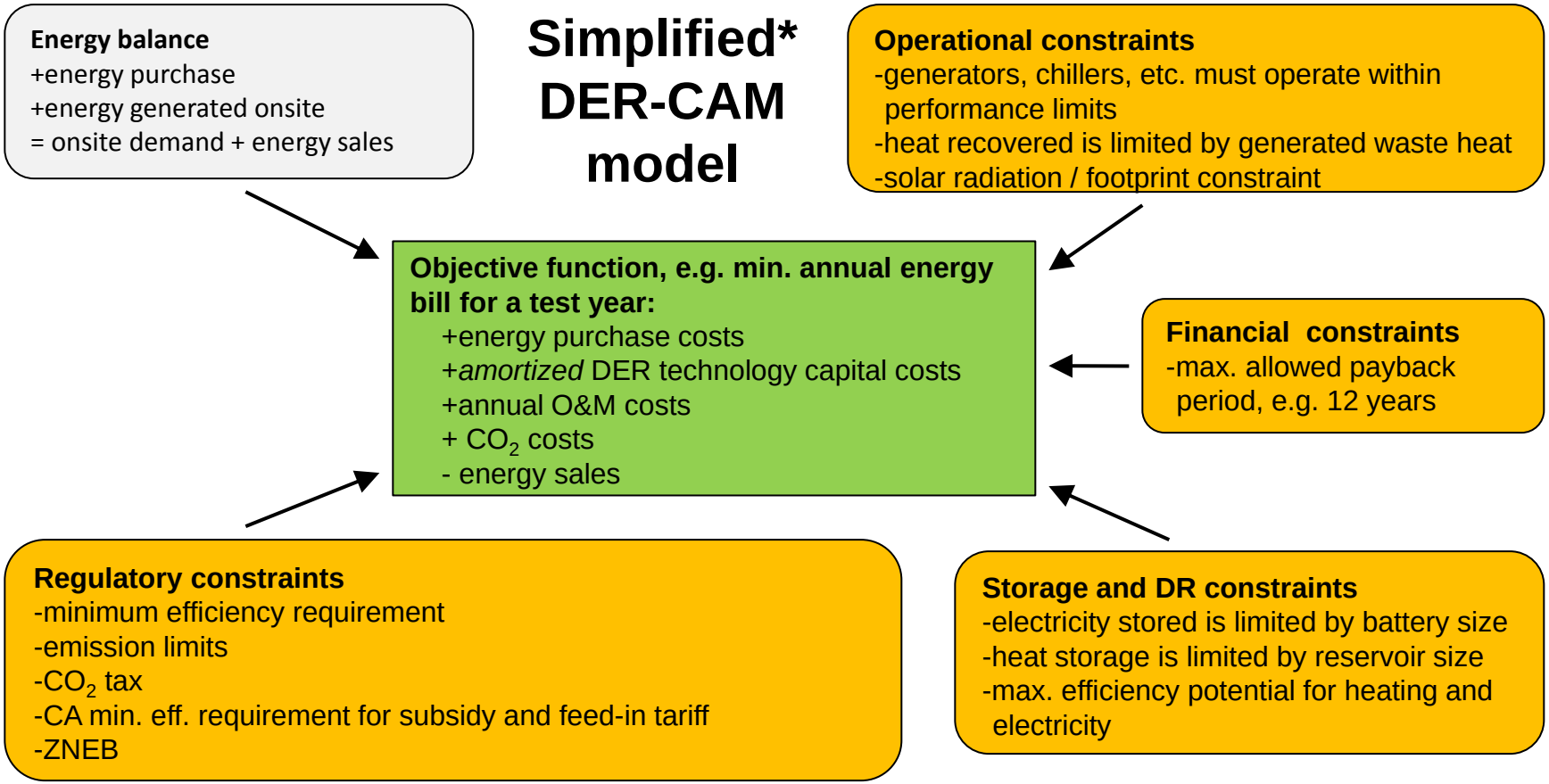
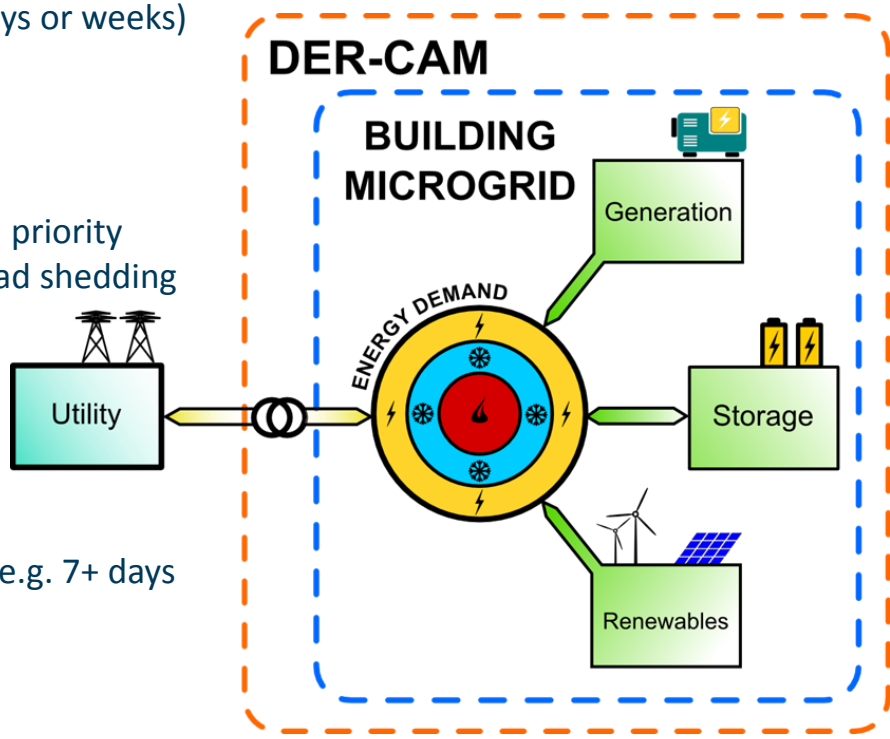


***does not show all constraints**

New features:
Microgrid Capabilities, Designed for Resiliency

- *Voluntary & forced islanding*
  - grid availability from reliability model: MTTF / MTTR
  - reliability measured by un-served energy
  - variable outage length (from a few minutes to several days or weeks)
  - voluntary islanding determined by microgrid economics
- *Load Prioritization / Critical loads*
  - user defined load priorities (up to 3 priority levels)
  - max. acceptable shedding amount and duration per load priority
  - economic trade-off for each priority level determines load shedding vs. backup DER
  - direct load control modelling
- *Optimize offline dispatch (islanded)*
  - energy management strategies (load shifting / shedding)
  - energy storage
  - resource availability – for extended times after outages, e.g. 7+ days
- *Plan backup generation*
  - trade-off: additional capacity vs. backup-only
  - offline fuel needs



DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

Our Partners and DER-CAM Licensees

Our Partners

Features and Applications

- DER Controller at University of New Mexico's Mechanical Engineering Building (UNM ME) in Albuquerque, New Mexico
- microgrid controller work at Fort Hunter Liggett , California

----------Backup slides for today----------

- microgrid capabilities and resilience at Fort Hunter Liggett considering critical loads

----------Not discussed today----------

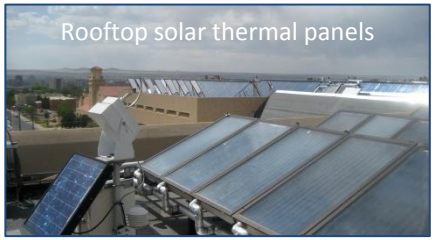
- remote access
- battery scheduling at Santa Rita Jail
- passive measures
- stepwise approximation of non-linear efficiency curves
- tracking of thermal storage temperature
- wind in DER-CAM
- electrochromic windows
- multi-year optimization (decision support)
- EV modelling
- CA CHP study

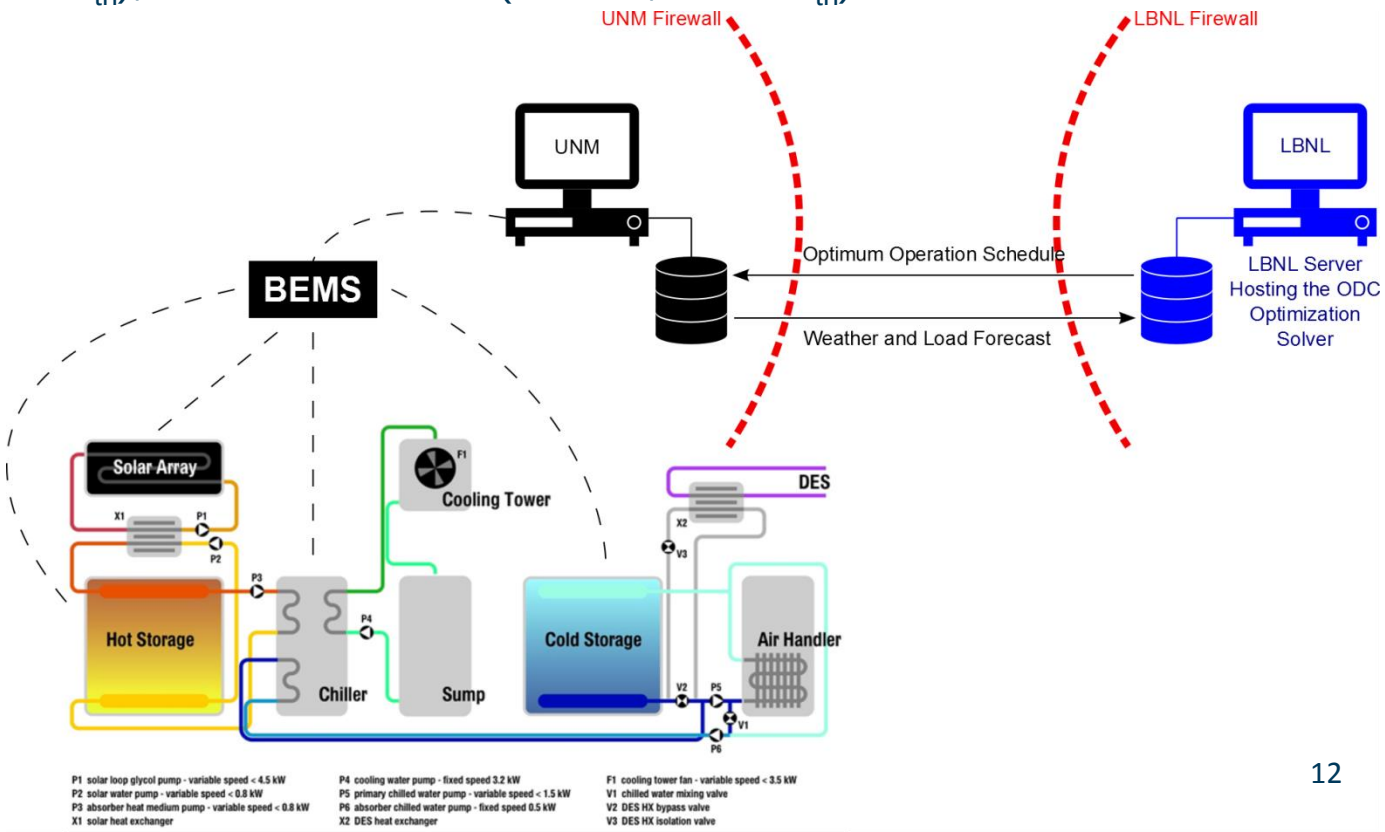
Application

DER Controller at University of New Mexico's Mechanical Engineering Building

UNM ME – DER Controller

- goal: use the Operations DER-CAM (ODC) in a Software-as-a-Service model for closed loop optimum cooling operation in the UNM ME
- technologies: heat storage (30 m^3, 510 kWh_{th}), cold storage (350 m^3, 2620 kWh_{th}), absorption chiller (70 kW_{th}), and solar thermal (232 m^2, 170 kW_{th})

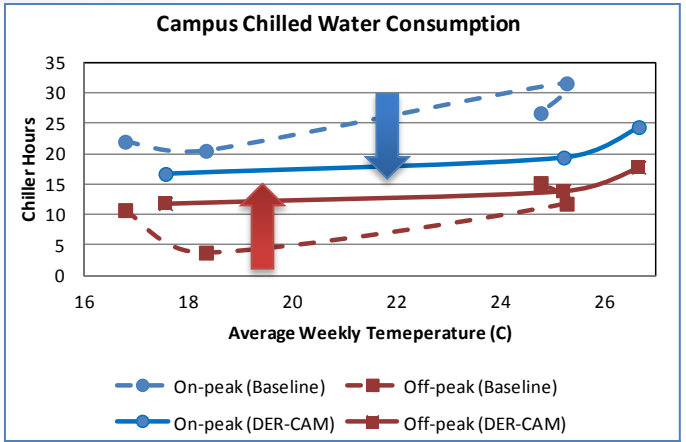


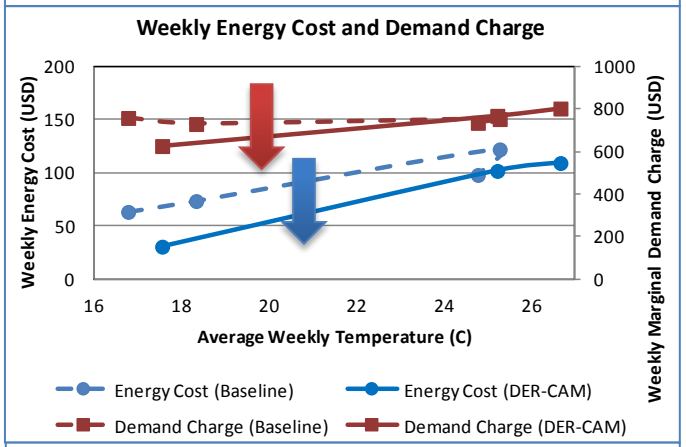


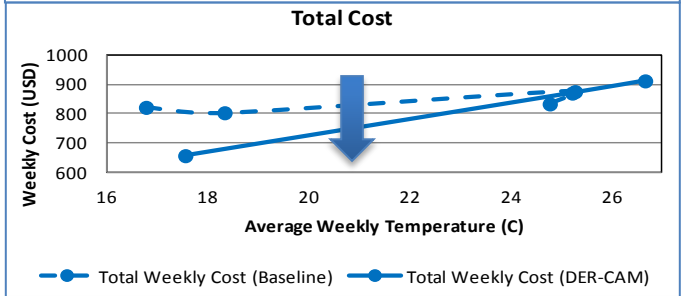
Savings with the DER-CAM Controller

- comparison of 3 DER-CAM operated and 4 baseline weeks in summer 2014:
  - week of 05 May 2014 - Baseline – 16.8 °C
  - week of 12 May 2014 - DER-CAM – 17.6 °C
  - week of 20 May 2014 - Baseline – 18.3 °C
  - week of 01 July 2014 - Baseline – 25.3 °C
  - week of 08 July 2014 - DER-CAM – 25.2 °C
  - week of 15 July 2014 - Baseline – 24.8 °C
  - week of 22 July 2014 - DER-CAM – 26.7 °C

- observations:
  - 55% saving in weekly energy cost
  - 16% saving in weekly marginal demand charge
  - 19% saving in total weekly cost

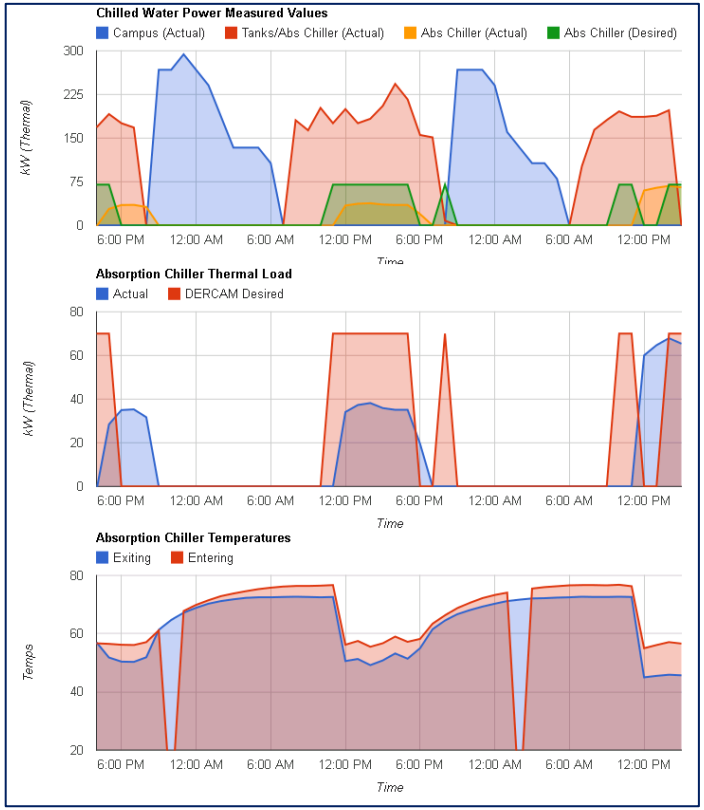


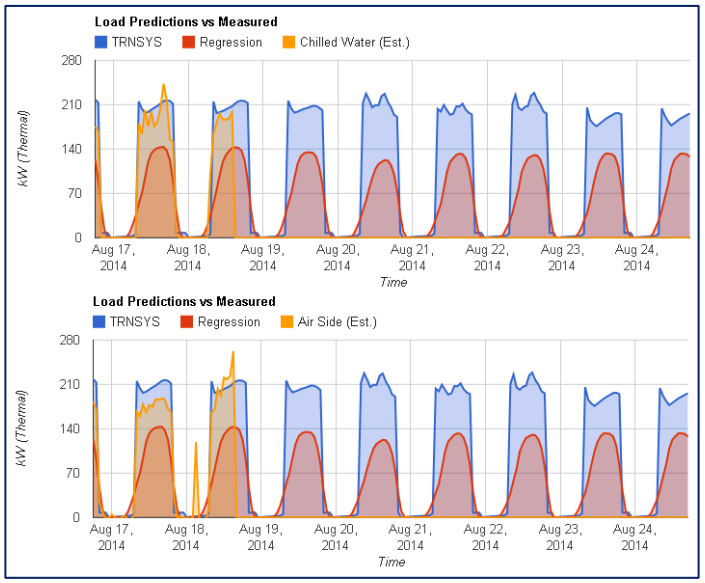




DER-CAM Online Interface at UNM ME

- online interface for the UNM ME operation (http://iseslab.unm.edu/dercam.html)
- measurements shown in real-time
- DER-CAM schedules depicted
- deviations from the optimum schedules visualized



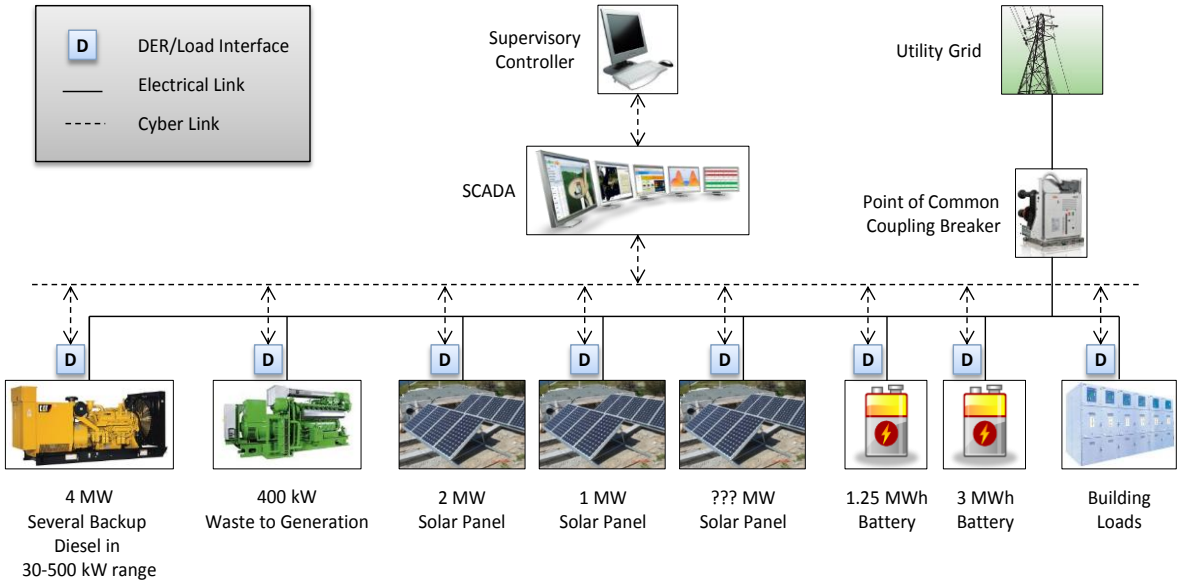


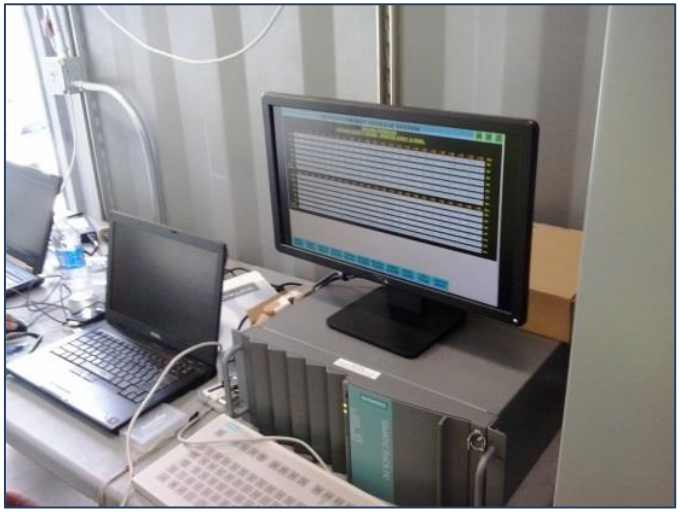
Application

Microgrid Controller Work at Fort Hunter Liggett

Fort Hunter Liggett – Technology Portfolio

- goal: use ODC-based supervisory microgrid controller to optimize operation schedules and limit grid export
- technologies: 2 MW of PV, 1.25 MWh battery, and 4 MW backup diesel, planned for several MW of PV, 3 MWh battery, and 400 kW waste to generation





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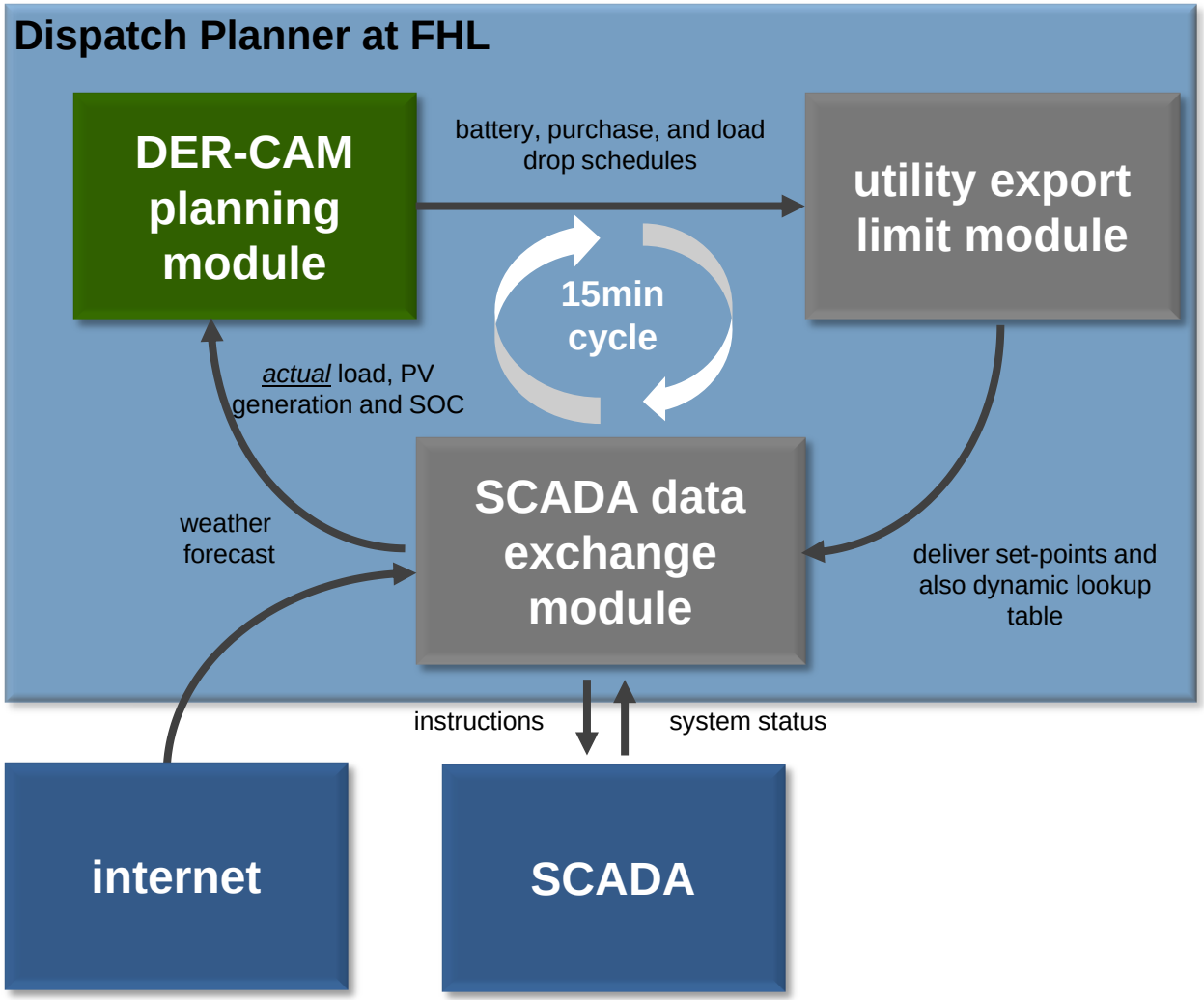
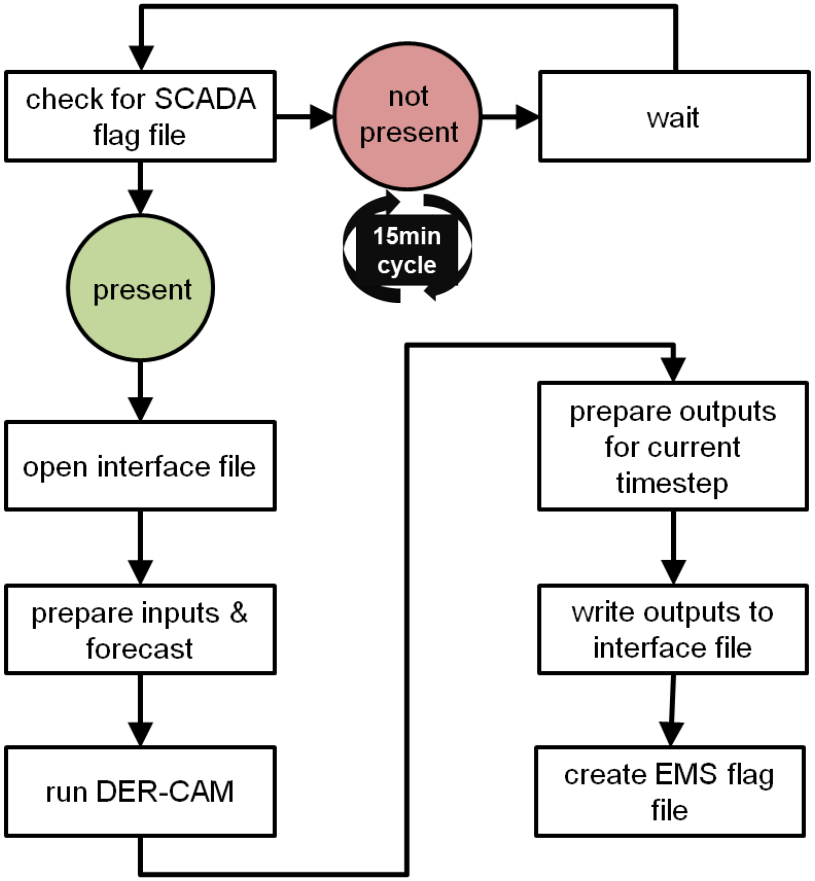
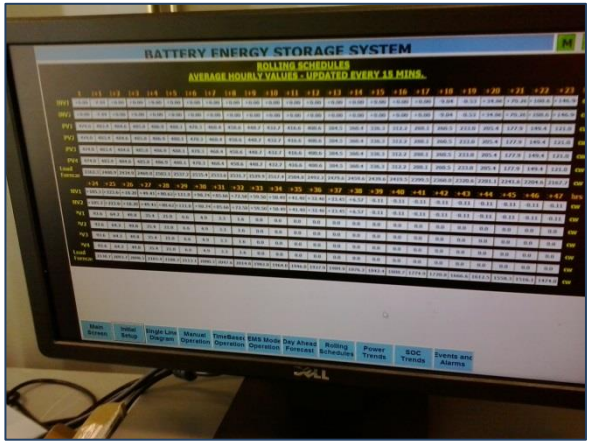
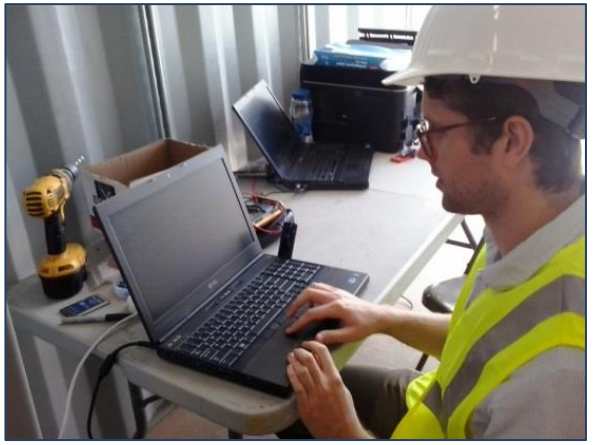


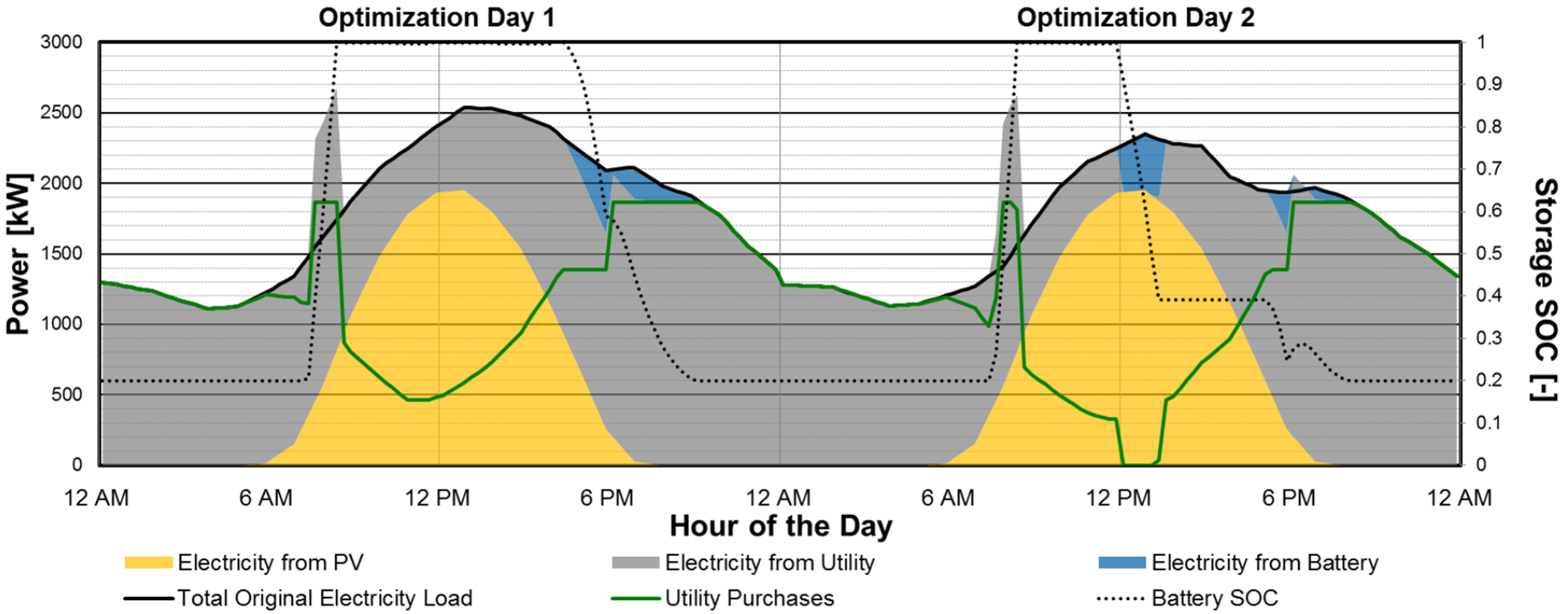
Successful Feeding of Operations DER-CAM Dispatches into the SCADA System







- two-days ahead predictive optimization
- PV and load forecasts are inputs to the ODC

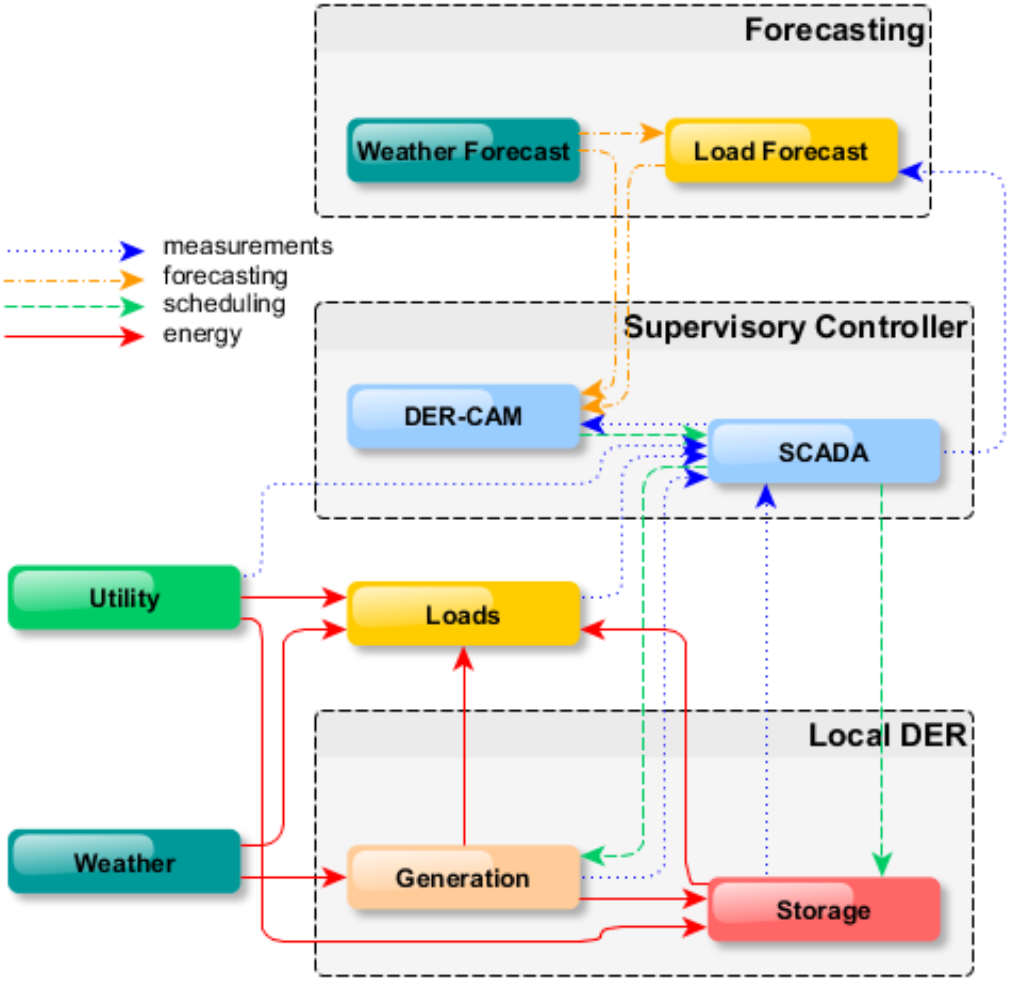


Final Application

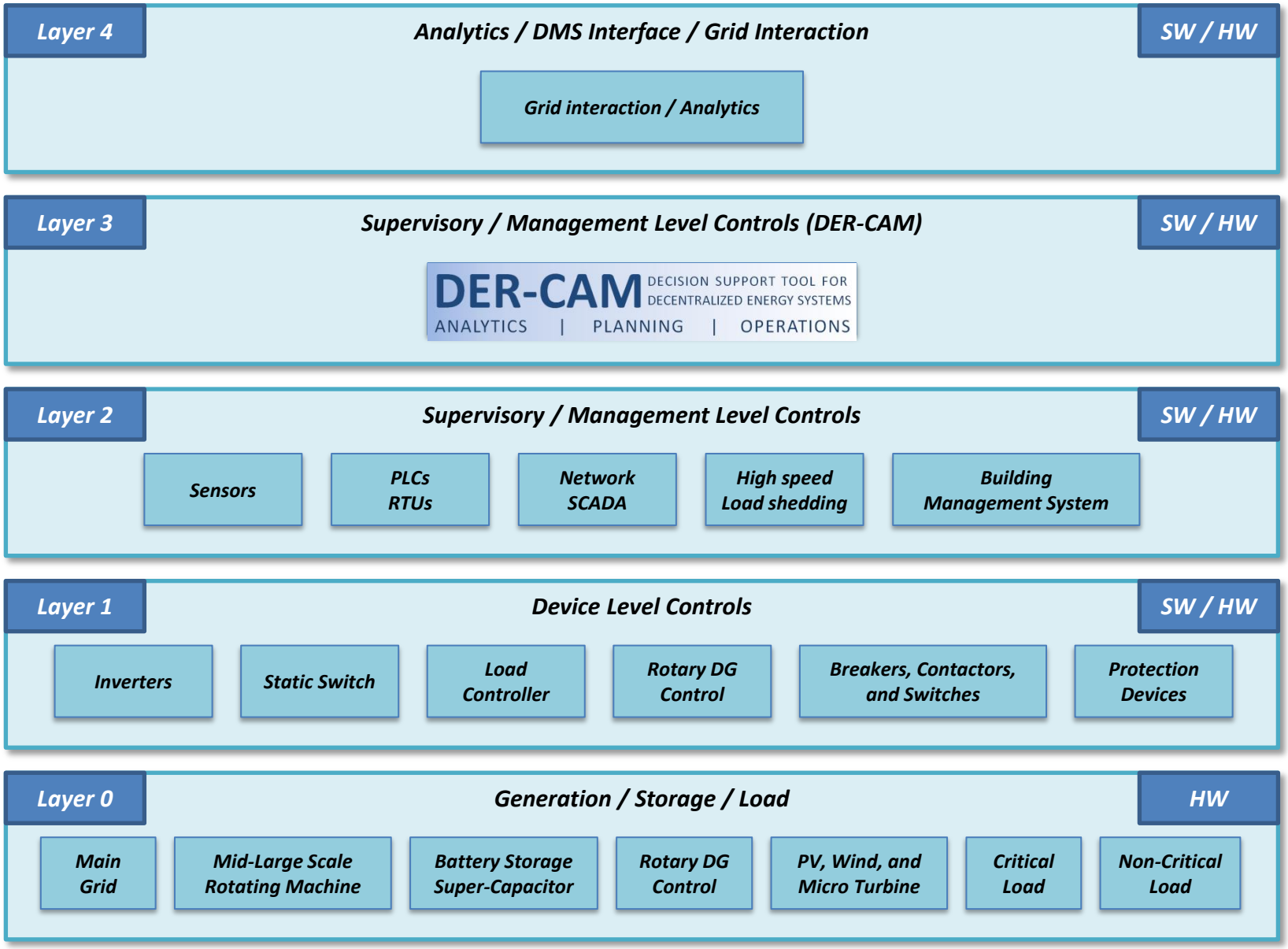
Multi-Layered Microgrid Controller with Utility Connectivity

Utility and Microgrid Interactions

schematic of physical and cyber interactions between utility, microgrid site, local resources, microgrid controller, and optimization problem



Layered Architecture for Utility-Interactive Microgrid



Questions and comments are very welcome!

BACKUP SLIDES

An Example of I&P DER-CAM Application

- site: Fort Hunter Liggett (FHL), an army base in Monterey County
- objective: use I&P DER-CAM to perform a quick assessment on optimal DER at FHL to enable microgrid capabilities, with focus on resilience against natural disasters.
- loads: 20% low priority, 70% medium priority, 10% high priority
- assessment type: DER-CAM assessment considering 24 hour blackouts, with:
  - existing DER
  - existing DER + additional PV and storage
  - existing DER + diesel backup generators
  - existing DER + additional PV, batteries, and diesel backup generators
  - existing DER + additional DER (full DER-CAM technology range)

An Example of I&P DER-CAM Application

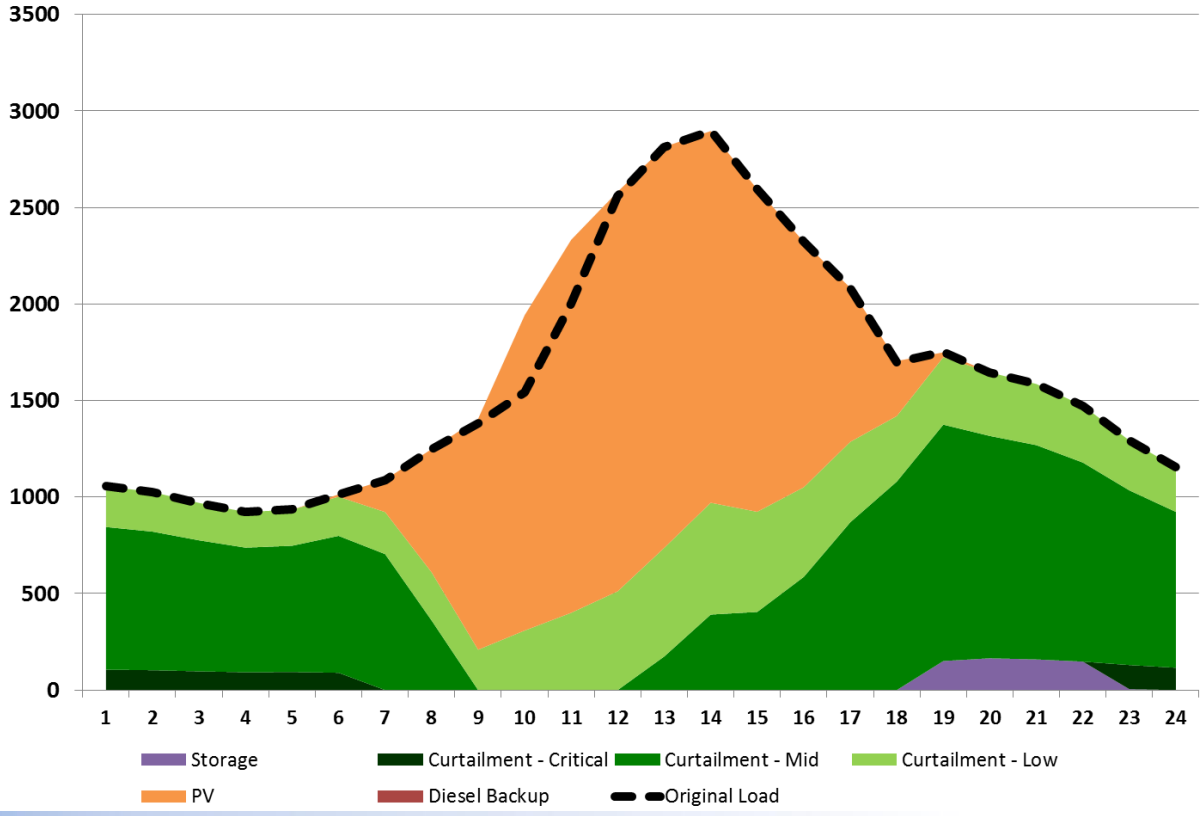
- DER-CAM assessment with 24h blackout (sales are not part of this analysis)
- results show that additional PV and storage, in addition to backup generation, will allow FHL to survive 24h outages without any major service disruption at lowest costs of all options
- when considering all DER options, the optimal investment solution allows enough flexibility to maintain operation during 24h outages and lowest costs

	Existing PV and Storage	Existing PV, Storage + Diesel Backup	Additional PV and Storage	Additional PV, Storage and Diesel Backup	All possible DER in DER-CAM
Annual Costs (million USD)	5.363	3.068	3.655	2.976	2.702
Annual CO_2 (ton)	4955	4973	2132	4119	4444
Photovoltaic (kW)	2000	2000	4936	3106	2077
Electric Storage (kWh)	1000	1000	20709	4374	1250
Diesel Backup (kW)	-	1400	-	1000	-
ICE (kW)	-	-	-	-	2000
CHP: ICE HX (kW)	-	-	-	-	500
Absorption Chiller (kW)	-	-	-	-	2807
Solar Thermal (kW)	-	-	-	-	801

(key results presented in the table)

An Example of I&P DER-CAM Application

existing PV and storage only: with the current PV and storage capacity alone, FHL would need severe curtailments in the event of a 24h outage, and would not be able to supply all loads



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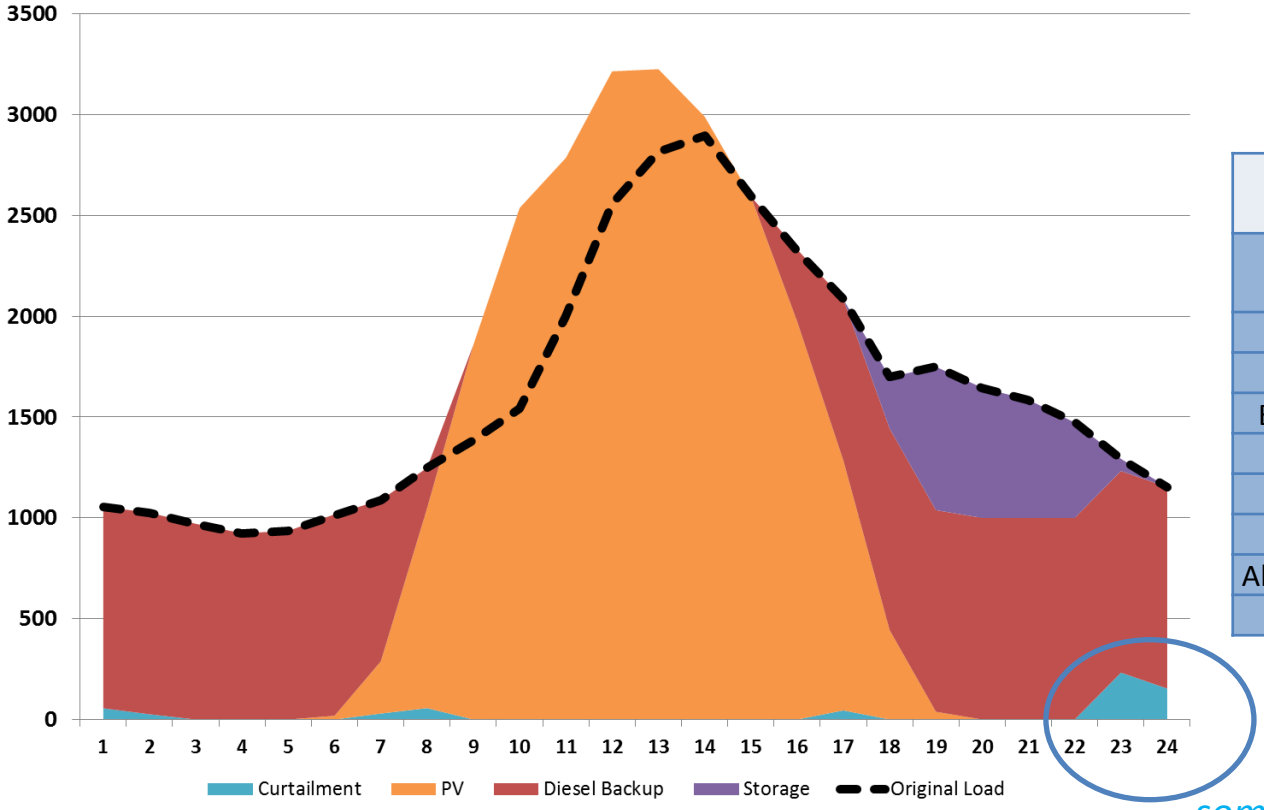
Electric Storage (kWh)	1000
Diesel Backup (kW)	-
ICE (kW)	-
CHP: ICE HX (kW)	-
Absorption Chiller (kW)	-
Solar Thermal (kW)	-

An Example of I&P DER-CAM Application

expansion of PV, batteries, and backup generators allowed: planned expansion of PV and Storage, together with diesel backup generators will allow increased resilience at FHL



	Additional PV, Storage and Diesel Backup
Annual Costs (million USD)	2.976
Annual CO_2 (ton)	4119
Photovoltaic (kW)	3106
Electric Storage (kWh)	4374
Diesel Backup (kW)	1000
ICE (kW)	-
CHP: ICE HX (kW)	-
Absorption Chiller (kW)	-
Solar Thermal (kW)	-

some load curtailment

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